The Large Synoptic Survey Telescope

Community involvement through Science Collaborations

Presentation to the Users’ Committee
October 10, 2007
The LSST Concept

- A deep survey of the observable sky
- Time domain sampling
- Address core science problems
- ... but also optimize to serve data for a broad range of problems
- Use (build) a high AΩ telescope
- Develop a data management facility and operations plan
- Make data public without delay
- Community participation for optimizing the science output
Enables Massively Parallel Astrophysics

- Dark matter/dark energy via weak lensing
- Dark matter/dark energy via baryon acoustic oscillations
- Dark energy via supernovae
- Dark energy via counts of clusters of galaxies
- Galactic Structure encompassing local group
- Dense astrometry over 20000 sq.deg: rare moving objects
- Gamma Ray Bursts and transients to high redshift
- Gravitational micro-lensing
- Strong galaxy & cluster lensing: physics of dark matter
- Multi-image lensed SN time delays: separate test of cosmology
- Variable stars/galaxies: black hole accretion
- QSO time delays vs z: independent test of dark energy
- Optical bursters to 25 mag: the unknown
- 5-band 27 mag photometric survey: unprecedented volume
- Solar System Probes: Earth-crossing asteroids, Comets, trans-Neptunian objects
Wide+Deep+Fast = Etendue
There are 22 LSSTC Institutional Members

Brookhaven National Laboratory
California Institute of Technology
Columbia University
Google, Inc.
Harvard-Smithsonian Center for Astrophysics
Johns Hopkins University
Kavli Institute for Particle Astrophysics and Cosmology - Stanford University
Las Cumbres Observatory Inc.
Lawrence Livermore National Laboratory
National Optical Astronomy Observatory
Princeton University
Research Corporation
Purdue University
Stanford Linear Accelerator Center
The Pennsylvania State University
The University of Arizona
University of California at Davis
University of California at Irvine
University of Illinois at Urbana-Champaign
University of Pennsylvania
University of Pittsburgh
University of Washington
LSST is a single project managed centrally with three subsystem teams
LSST has Passed Two Significant Milestones in 2007

- Construction proposal was submitted to the NSF in February 2007
  - 60 Month Construction and Commissioning
  - Ready for MREFC Funds in FY2010
  - Proposed as Public Private Partnership to Share costs
    - NSF MREFC - $242 M
    - DOE HEP - $96 M
    - Private - $52 M

- NSF CoDR held September 2007
  - Panel Unanimously Recommended LSST to Proceed to PDR (Fall 2008)
  - Panel was “very impressed by strength, depth and breadth of LSST team”
  - Telescope & Site designs and Data Management design exceeded CoDR Requirements

(FY06 $ with Contingency)
# LSST Timeline Based on Agency Guidance Following CoDR in September, ‘07

<table>
<thead>
<tr>
<th>FY-07</th>
<th>FY-08</th>
<th>FY-09</th>
<th>FY-10</th>
<th>FY-11</th>
<th>FY-12</th>
<th>FY-13</th>
<th>FY-14</th>
<th>FY-15</th>
<th>FY-16</th>
<th>FY-17</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NSF D&amp;D Funding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MREFC Proposal Submission</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSF CoDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MREFC Readiness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSF PDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSF CDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NSF MREFC Funding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telescope First Light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System First Light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commissioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DOE MIE Funding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Fabrication (5 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor Procurement Starts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE CD-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DOE Ops Funding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera I&amp;C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Ready to Install</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Delivered to Chile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DOE R&amp;D Funding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE CD-0 (Q1-06)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE CD-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE CD-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE CD-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE CD-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: White boxes indicate months without funding or milestones.

- MREFC Proposal Submission
- NSF CoDR
- MREFC Readiness
- NSF PDR
- NSF CDR
- NSF MREFC Funding
- Telescope First Light
- System First Light
- Commissioning
- ORR
- DOE MIE Funding
- Camera Fabrication (5 years)
- Sensor Procurement Starts
- DOE CD-3
- DOE Ops Funding
- Camera I&C
- Camera Ready to Install
- Camera Delivered to Chile
- DOE CD-4
- DOE R&D Funding
- DOE CD-0 (Q1-06)
- DOE CD-1
- DOE CD-2
- DOE CD-3
- DOE CD-4

DOE CD-0 (Q1-06) refers to the first quarter of 2006.
The LSST will be sited at Cerro Pachón in Northern Chile
Key Performance Requirements

- **8.4 meter primary aperture**
- **3.5 degree field of view with fast f/1.2 beam**
- **Tight control of systematic error**
  - Ellipticity measurements
  - PSF shape control
  - Delivered Image Quality – 0.3” FWHM
- **High Duty Cycle and Efficiency**
  - 30 seconds per pointing, all night, each night for 10 years
  - Two 15 second exposures / visit
  - “5 Sec slew & settle” between visits
  - Limited downtime
  - Unscheduled downtime < 3%
  - Maintenance support

---

20,000 square degrees in 10 years
1 exposure depth = 24.5 AB Mag. (R-band)
Median PSF full width half max image = 0.67 “
Median PSF ellipticity = 0.04
NOAO leads the Telescope and Site Development
SLAC (DOE) Leads the Camera Development

Filter/Shutter Mechanisms

Camera Body
Cryostat Design

Sensor/Raft Development

Electronics

Metrology/Calibration

Typical Raft

Pattern Produced By One Laser Head On Full Sized FPA With 150 X 40 Line/mm Crossed Ronchi Gratings
Unprecedented Astronomy Data Volumes

Estimated Nightly Data Volumes

- LSST Estimated Nightly Data Volumes
  - 10 X Pan-STARRS 4
  - 100 X Sloan Digital Sky Survey (SDSS)
  - LSST data archive Increases ~ 7 PB/yr.
  - Requires scalability and reliability in LSST data management systems well beyond pre-cursors.
Core Science Drives the LSST Requirements

• **Dark Energy / Matter**
  – Weak lensing: **PSF Shape, Image Depth, Survey Area**
  – Super Novae + Photo z: **Filters, Photometric Precision**

• **Map of Solar System Bodies**
  – NEA: **Temporal Sampling**
  – KBO: **Depth, Colors**

• **Optical Transients and Time Domain**
  – GRB Afterglows: **Image Differencing**
  – Unknown transients: **Pipeline Latency**

• **Assembly of the Galaxy and Solar Neighborhood**
  – Galactic Potential from RR-Lyrae Stars: **Temporal Sampling, Photometry**
  – Galactic Halo Structure and Streams: **Proper Motion Astrometry**
  – Census to >500pc: **Parallax Astrometry**
Data Acquisition Planning

- Trade space for data acquisition:
  - Area, passbands, average re-visit frequency
  - Physical Limitations for all 3 above
  - Target accessibility at any given time goes as clockwork
  - Weather is random, but with broad average seasonal patterns
  - Other constraints: e.g. filter choice vs sky brightness
  - Need for a simulator/scheduler: scheduling algorithm that adapts with time
  - Test data suitability from simulator runs, and use it to optimize data acquisition strategy
Users’ Committee
10 October 2007

Simulator Output
Data Products

- Raw data stored and accessible
- Real-time alerts of transient events
  - trigger follow-up observations at other facilities
- Continually improving catalog(s) of objects
  - “Source” catalog (individual exposures, retains time domain)
  - “Object” catalog (object based, for static studies)
- These are the MAIN science resource (ala SDSS)
- Continually improving stacked image of “static sky”
Community Engagement

- LSST Data Publicly Available
  - No proprietary period
- Science will be carried out by community
- Need community input now
  - More detailed science case
  - Cadence
  - Observing strategy
  - Calibration strategy
  - Software and database design
  - Data products
- Will need community assistance with
  - Commissioning, quality assessment
Community Participation

Science Collaborations

- **Specific Topics**
  - Work out science strategy in detail
  - Conduct precursor work if required
- **Overall Chair: Michael Strauss (Princeton)**
- **No funding from LSSTC**
  - MREFC funds cannot cover science
  - Groups may seek funding from NSF grants program
  - DOE will fund through existing operating grants
- **Initial Membership**
  - Drawn from LSST member institutions and those who have already contributed substantial amount of work toward realizing the LSST
  - Initial chairs selected; groups will subsequently elect own chairs
- **Open Call for Community Participation**
  - 2006 December (estimated)
LSST continues with strong support and broad interest

| LSST SCIENCE COLLABORATIONS |
|-----------------------------|-----------------------------|
| **Science Program**         | **Program Chair**           |
| Weak Lensing                | B. Jain (U. Penn) and D. Wittman (UCD), Co-Chairs |
| Strong Lensing              | P. Marshall (UCSB)          |
| Supernovae                  | M. Wood-Vasey (CfA)        |
| Large Scale Structure and Baryon Oscillations | A. Hamilton (U. Colorado) |
| Galaxies                    | H. Ferguson (STScI)        |
| Active Galactic Nuclei      | N. Brandt (Penn State U.)  |
| Milky Way Structure         | C. Rockosi (UCSC)          |
| Stellar Populations         | A. Saha (NOAO)             |
| Transients/Variable Stars   | S. Kulkarni (Caltech)      |
| Solar System Science        | S. Chesley (JPL)           |
Proposal to Join Collaboration

- Submitted to NOAO and reviewed by NOAO and SLAC
  - Ensure process is open, merit-based
  - Recommendations for membership submitted to LSST Director (Tyson) and LSST Board for approval

- Proposers can
  - Propose to join existing group
  - Propose to establish a new group in an existing or new area

- Proposals will be evaluated on the basis of
  - Planned contribution to chosen science collaboration
  - Planned commitment of time and/or resources to preparatory work
  - Unique skills or knowledge brought to the collaboration
Community Solicitation

- **All data products will be available to the community as well as to the collaborations**
  - All products available through Virtual Observatory interface
- **Joining a collaboration most appropriate if science has special requirements, e.g.**
  - Control/Measurement of image shape (weak lensing)
  - Calibration
    - Photo z’s
    - Astrometry
  - Interfacing specialized pipeline to data system
  - Cadence (variable stars, NEOs)
  - Etc.
Status of Call for Collaborations

- A baseline simulation for a ten year run of LSST has been made, and is ready for public access.

- A pre-call for participation in LSST via the science collaborations has been announced through the NOAO newsletter, and a parallel call to the physics community will be out shortly.

- NOAO is hosting a help desk for answering questions.

- We are in the process of drafting application forms for the participation, and working out details of the selection process.
Ground Rules Governing Selection Process

• Proposals will be judged on merit, commitment, and what proposers bring intellectually and as ancillary support to the project

• There is no monetary award: only the opportunity to participate in building the science program into further system and operations design

• Separate proposal modes for:
  a) individual joining an existing collaboration
  b) starting a new collaboration (can propose a seed group)

• Proposals will be evaluated jointly for astro and physics (also NSF and DOE) communities. NOAO and SLAC will design and co-host the process